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ORIGINAL ARTICLE

Effects of back posture education on elementary schoolchildren's back function

Elisabeth Geldhof · Greet Cardon · Ilse De Bourdeaudhuij · Lieven Danneels · Pascal Coorevits · Guy Vanderstraeten · Dirk De Clercq

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Abstract The possible effects of back education on children's back function were never evaluated. Therefore, main aim of the present study was to evaluate the effects of back education in elementary schoolchildren on back function parameters. Since the reliability of back function measurement in children is poorly defined, another objective was to test the selected instruments for reliability in 8–11-year olds. The multi-factorial intervention lasting two school-years consisted of a back education program and the stimulation of postural dynamism in the class. Trunk muscle endurance, leg muscle capacity and spinal curvature were evaluated in a pre-post design including 41 children who received the back education program (mean age at post-test: 11.2 ± 0.9 years) and 28 controls (mean age at post-test: 11.4 ± 0.6 years). Besides, test–retest reliability with a 1-week interval was investigated in a separate sample. Therefore, 47 children (mean age: 10.1 ± 0.5 years) were tested for reliability of trunk muscle endurance and 40 children (mean age: 10.2 ± 0.7 years) for the assessment of spinal curvatures. Reliability of endurance testing was very good to good for the trunk flexors (ICC = 0.82) and trunk extensors (ICC = 0.63). The assessment of the thoracic (ICC = 0.69) and the lumbar curvature (ICC = 0.52) in seating position showed good to acceptable reliability. Low ICCs were found for the assessment of the thoracic (ICC = 0.39) and the lumbar curvature (ICC = 0.37) in stance. The effects of 2 year back education showed an increase in trunk flexor endurance in the intervention group compared to a decrease in the controls and a trend towards significance for a higher increase in trunk extensor endurance in the intervention group. For leg muscle capacity and spinal curvature no intervention effects were found. The small samples recommend cautious interpretation of intervention effects. However, the present study's findings favor the implementation of back education with focus on postural dynamism in the class as an integral part of the elementary school curriculum in the scope of optimizing spinal loading through the school environment.

Keywords Back education program · Prevention · Schoolchildren · Back function

E. Geldhof · G. Cardon (✉) · I. De Bourdeaudhuij · D. De Clercq
Department of Movement and Sports Sciences, Ghent University, Watersportlaan 2, 9000 Ghent, Belgium
e-mail: greet.cardon@ugent.be

L. Danneels · P. Coorevits · G. Vanderstraeten
Department of Rehabilitation Sciences and Physiotherapy, Ghent University, De Pintelaan 185, 6K3, 9000 Ghent, Belgium

P. Coorevits
RAMIT vzw c/o Department of Medical Informatics and Statistics, University Hospital, Building K3-5th Floor, De Pintelaan 185, 9000 Ghent, Belgium

Introduction

The high prevalence of low back pain (LBP), the increasing levels of non-specific LBP among youngsters in our society and the indications that juvenile and adult LBP are related [4, 17] suggest the need for research into the early stages of the problem.

The multi-factorial nature of the risk for back pain in childhood and adolescence is widely accepted [23, 24].

Recent studies have demonstrated that psychosocial factors play an important role in children's self-reported back pain [21, 22, 48]. However, the underlying mechanisms for back pain at young age remain unclear and most reported factors associated with back pain reports in childhood are still controversial [6].

Based on a previous study [16], the implementation of a multi-factorial back posture program with focus on postural dynamism through the school curriculum showed significant improvement in children's postural behavior during material handling and decreased duration of trunk flexion, neck flexion and neck torsion during lesson time. In contrast, the intervention did not affect children's back pain reports or fear-avoidance beliefs. An interesting research question included whether in children, the change towards biomechanical favorable postural behavior was associated with an improvement of the underlying mechanisms for postural behavior, namely back functioning. In the evaluation of back function with respect to postural behavior, both muscle activity and spinal curvature are important aspects. To the author's knowledge the possible effects of a school-based multi-factorial back posture program on children's back function have never been evaluated.

As a first aspect of back function we focus on children's trunk muscle capacity. The literature pointed out that low endurance of trunk flexors was a risk indicator for recurrent and nonspecific LBP in a group of adolescents [23] and insufficient trunk extensor endurance was associated with adolescents' present and future LBP [41]. Consistently, Salminen [39] found in his cross-sectional study a decreased isometric endurance of both trunk extensors and flexors among LBP sufferers at the age of 15 years. In contrast to the consistent study findings on trunk muscle endurance, research on the relationship between trunk muscle strength and back pain reports in adolescents revealed conflicting findings. Newcomer et al. [33] found that back pain was associated with decreased trunk muscle strength in 10–19-year olds. On the other hand, Balagué et al. [3] could not establish a relation between isokinetic trunk muscle strength and history of LBP in 10–16-year olds. In agreement Feldman et al. [15] demonstrated that poor isometric trunk flexor strength was not a risk factor for the development of LBP in adolescents. Furthermore, an imbalance in trunk muscle strength was identified as a risk factor for LBP in 15–19-year olds. It was demonstrated that a reduced development of trunk extensors compared to trunk flexors was a predictor for future LBP [27]. Based on the literature, one could thus suggest that both trunk muscle strength and trunk muscle endurance may have an influence on LBP at young age. However, in terms of spinal protection, there are indications that trunk muscle endurance can have more influence on LBP than trunk muscle strength since fatigued muscles may leave the spine structures more vulnerable resulting in uncontrolled spinal motions [1].

A second aspect of back function embraces the strength capacity of the leg muscles. The relationship between lifting and low back problems is recognized in adult populations performing work-related activities. Therefore, some ergonomic prevention programs for LBP in adults pay attention to biomechanical favorable lifting techniques, such as the squat technique [45]. Performing a squat correctly requires sufficient strength in the leg muscles. In addition, Lee et al. [26] found reduced leg muscle capacity and trunk muscle strength in adults with LBP. Correspondingly, Suter and Lindsay [43] found that patients with LBP had higher than normal inhibition in their quadriceps muscles, which resulted in reduced functional capacity of the leg muscles. However, to the authors' knowledge no earlier work investigated children's leg muscle capacity in association to back pain. Although, one may assume that children need adequate leg muscles to perform lifting tasks and multiple activities during daily life.

The spinal curvature was included as a third aspect of back function since the general principle for an optimal load distribution in the human body is a neutral spinal curvature. In the study of Salminen et al. [40] 33% of the young individuals aged 14-year old demonstrated abnormalities of the spinal structures. The latter study findings indicated that even at a young age the spinal structures may undergo degenerative changes. On the other hand, Widhe et al. [49] reported that back pain was not related to children's posture and the study of Poussa et al. [37] suggested that spinal posture did not predict back pain assessing children's sagittal posture at age 11–14 and later at age 22 years.

Taking the latter into account, only a small number of studies investigated the relationship between back functioning and back pain reporting at young age. The limited studies reported conflicting results and the multi-factorial risk for back pain reporting at young age indicates that other factors as well play a significant role in children's self-reported back pain, e.g. psychosocial factors [22, 48]. So, the literature provides no conclusive evidence regarding the relationship between functional risk factors and back pain at young age. However, trunk muscle endurance, leg muscle capacity and the spinal curvature are three important determinants for adequate back function. Accordingly, good back functioning is a decisive factor for good spinal loading and could thus play a critical role within optimal daily loading. As such, in the scope of optimal daily loading, an adequate back function in young individuals could possibly play a part in the multidimensional approach to prevent back pain. However, it was never investigated whether back education could result in optimized back function at elementary school-age. Therefore, the main purpose of the current study was to evaluate in elementary schoolchildren the effects of a two-school-year promotion of good body mechanics on back function with regard to trunk muscle endurance, leg muscle capacity and spinal curvature.

Measuring back function in 9–12-year olds is only useful when reliability is determined. Most studies on the reliability of test methods have been carried out in adults while a minority has been carried out in adolescents and children. In the same line, the reliability for trunk extensor and trunk flexor endurance testing was found to be good in adolescents [32, 35] and adult populations [2, 5, 14, 21, 24, 34]. However, reliability studies on trunk muscle endurance performance testing in children at elementary school age could not be located. Additionally, the non-invasive objective assessment of static curvatures using the Zebris® system was never used to evaluate children's spinal curvatures. As a result, another important objective of the current study was to test trunk muscle endurance performance and the Zebris® technique for reliability in children at elementary school-age. Test–retest measurement for isokinetic leg strength was not investigated in the current study since isokinetic testing of the knee flexors and knee extensors is well documented in children [10] as in adults [11].

Materials and methods

Subjects

Intervention effects

The multi-factorial back education program was implemented in eight Flemish elementary schools, which were selected by simple randomization. All schools were comparable with regard to geographic location and parental education levels. Before the start of the intervention study, children were randomized at school-level into the intervention and the control group (ten intervention class groups out of four schools, ten control class groups out of four schools). All teachers were only associated to one particular school excluding risk of contamination. The parents of all participants signed an informed consent form.

In order to evaluate the effects of the back posture program on children's back function, the present study sample including children out of four randomly selected elementary schools (two intervention and two control schools) was drawn for more in depth measurement. At pre-test, the parents of all 197 fourth and the fifth graders out of four schools were notified by a letter and asked for the participation of their child. A total of 77 parents signed the informed consent form (44 intervention parents and 33 control parents). All 77 children performed the back function measurements at pre-test. Eight children dropped out at post-test (three intervention children and five controls). Finally, the intervention group consisted of 41 participants (19 boys, 22 girls; mean age at post-test 11.2 ± 0.9 years) and the control group included 28 children (11 boys, 17 girls; mean age at post-test 11.4 ± 0.6 years). The participants of the in depth measurements showed no differences for chronological age when compared to the non-responders ($t = 0.601$, ns). Correspondingly, at baseline anthropometrics showed no significant differences between responders and non-responders (weight: $t = 0.220$, ns; height: $t = 1.336$, ns), as well as the change of children's weight and height over the two intervention years showed no differences between both groups (change in weight: $t = 0.056$, ns; change in height: $t = 1.217$, ns). Additionally, no differences were found for their self-reporting on total amount of physical activity per week ($t = 0.726$, ns).

The study protocol was approved by the Ethical Committee of the University Hospital of the Ghent University.

Test–retest reliability

Test–retest reliability for back function measurements was investigated in a separate sample of elementary schoolchildren. Out of a simply randomized selected school, the parents of all fourth and fifth graders ($n = 153$) were contacted. This invitation was accepted by 87 parents who signed the informed consent form for their child. Out of this group, children were randomly allocated to the study sample-evaluating test–retest reliability for either trunk muscle endurance ($n = 47$; mean age: 10.1 ± 0.5 years) or spinal curvature assessment ($n = 40$; mean age: 10.2 ± 0.7 years).

Intervention

The multi-factorial intervention consisted of a back education program and the stimulation of postural dynamism in the class through systematical support and environmental changes with active involvement of the class teacher, as described in a previous study [16]. 'Postural dynamism' stands for frequent posture changes in addition to variable and dynamical activities. The back posture intervention was integrated into the elementary school curriculum within the lessons health education. As such, the children of the intervention group did not receive additional lessons. Control teachers educated other health-related topics, such as dental hygiene.

Back education

The basic program consisted of six back education lessons at 1-week interval, taught by a physical therapist to one class group at a time. Pupils were taught anatomy and pathology of the back in the context of optimal loading of the body structures. Furthermore, the basic principles of biomechanical favorable postures during standing, sitting, lying, lifting, pushing and bending were taught and practiced. In addition to the six back education sessions, didactic material was provided for the class teachers and guidelines were presented in order to optimize integration of the learned back posture principles.

Support and environmental influence

The multi-factorial intervention incorporated an extra focus on postural dynamism in the class. Therefore two basic principles were elaborated: stimulation of dynamical sitting and prevention of prolonged static sitting. In order to stimulate dynamical sitting, active and variable sitting were reinforced by providing two pezzi balls, a dynair and a wedge in each classroom. The children passed the ergonomic elements systematically in the recess after two lessons. Further, in order to interrupt prolonged static sitting, short movement breaks between the lessons were introduced. Twice a day movement breaks were organized in the class, supplementary to the recess. Additionally class teachers were encouraged to teach following an activating approach (e.g. distribution of handouts systematically through children, use of sitting alternatives, variable work organizations like standing work places) and to change structural aspects in the class organization (e.g. decentralized storing places for educational tools, textbooks and schoolbags).

Procedure

Test–retest reliability

The reproducibility study in 8–11-year olds for trunk muscle endurance and spinal curvature assessment included test and retest measurement with a 1-week interval. Test and retest measurements were performed by the same researchers and took place on the same day of the week. The subjects' measurement order, test mode, testing sequence and surrounding factors were identical during the two measurement sessions. The test-settings were identical to the evaluation of the back function measurements as described below.

Intervention effects

Pre-testing occurred during September and October 2002. The multi-factorial intervention started in November 2002 for the following two school-years. Post-testing was performed from April until June 2004. The children were tested in the Centre for Sports Medicine at the Ghent University Hospital. Therefore, parents were asked by phone to make an appointment on a Wednesday afternoon or a Saturday morning, when Flemish children do not attend school. On one of the ten proposed testing days, the children performed the back function measurements taking about 1 h. The evaluation consisted of back function measurements with regard to trunk muscle endurance, leg muscle capacity and spinal curvature.

On the day of testing, children's age and basic anthropometrical data were registered before starting the functional measurements. Weight was assessed to the nearest 0.1 kg (Seca, max 200 kg). Using a wall-mounted stadiometer (Siber Hegner), height was measured to the nearest 1 mm. Children were moved to the functional measurements in a variable order, as a position became available for testing. For each child, the test sequence and the required 20 min rest between two physical exertions was supervised by a test leader. Children were barefoot and a standardized test-setting was used for the three measurements, as described below. During the measurements of trunk muscle endurance and leg muscle capacity, children were given verbal encouragement in a consistent way to achieve their best performance. The test leaders were blinded to group assignment.

In the scope of another study [8], children's physical activity pattern was assessed completing a questionnaire with parental assistance, which showed good reproducibility and validity [46]. Children's amount of physical activity was assessed by asking for their main sports in leisure time with a maximum of three sports, participated in organized as well as non-organized involvement.

Evaluation instruments

Capacity of the leg muscles

A calibrated isokinetic testing machine (Biodex System 3 Pro, Biodex Corp., Shirley, NY, USA) was used for bilateral leg muscle capacity. Since velocity affects torque [12], the 'Isokinetic Bilateral—Knee (extension/flexion)—Conc/Conc 60/60 180/180' test was selected to measure children's knee extension and knee flexion capacity of both legs. This test assessed each leg at two velocities, evaluating maximal strength at low speed (60°/s, 5 repetitions, high resistance) and endurance at high speed (180°/s, 15 repetitions, low resistance). Therefore, the child was seated upright on the adjustable chair of the Biodex with the axis of the dynamometer corresponding to the knee joint axis of the active leg. The active leg was fixed with a strap at the thigh. The cuff was secured approximately 2 cm superior to the lateral malleolus of the ankle. Before the start of the test, the range of motion (ROM) was set up for the active leg. The ROM was determined by the horizontal position of the extended leg towards the smallest flexed position. Children were instructed to perform the 'slow speed' and the 'fast speed' extension/flexion tests maximally. Additionally, the test leader informed the children about the three training trials before both tests, the 10 s rest between the two tests at different angular velocities and the identical protocol for both legs. The outcome parameters were 'maximal torque/body weight' (%), 'total work' (Joule) and 'average power' (Watt). Each leg muscle parameter comprised the sum score of bilateral flexion and extension at the two velocities, consistent with the measurement of leg muscle strength by Ho et al. [20].

Trunk muscle endurance

Trunk extensor endurance testing

Based on the method of Sörensen [5], children's isometric endurance of the trunk extensors was evaluated, as presented in Fig. 1. Therefore, the subject was lying prone with extended legs and the cranial border of the iliac crest (SIAS) at the edge of a research table. In the present study the legs were fixed with two belts: one across the middle of the gluteal regions and one across the gastrocnemius zone. After positioning the subject on the research table with decreased inclination under an angle of 35°, the subject had to bring the head and the upper part of the body unsupported through a horizontal position with the arms in a 'wing position'. Sitting at eye-level of the table-leaf, the researcher supervised that the correct horizontal posture was maintained in the sagittal plane. The subject kept the horizontal position until exhausted. The score for the trunk extensor endurance testing was the endurance time, measured with a stopwatch, for a maximum of 240 s as originally prescribed [5].

Fig. 1 The trunk extensor endurance test

Trunk flexor endurance testing

Based on the literature [30–32, 38], the static curl was used to determine trunk flexor endurance, as presented in Fig. 2. Therefore, the subjects were in a supine position on a research table with the legs fixed by a belt proximal to the knee-joint. Before the start of the endurance test, children's inferior angle of the scapulae were marked standing in an anatomical position and the two marks were connected with tape. With the arms crossed on the shoulders, the subjects had to curl up until the researcher could see the taped line between the inferior angles of the scapulae. The children maintained this flexed position as long as possible, with a maximum of 240 s. During testing the researcher checked whether the posture was steady. If the tester

Fig. 2 The trunk flexor endurance test

could no longer see the taped line on the back of the child, the correct posture was lost and the test was stopped. The endurance time was recorded with a stopwatch.

Static back curvatures

An ultrasound analysis system (Zebris CMS70P, Isny, Germany) and the accompanying WinData software were used for the objective assessment of static back curvatures by three-dimensional opto-electronic recording. Previous research including adult study samples reported sufficient reproducibility, accuracy and validity for use of the Zebris technique [28, 29, 42, 47]. The system consisted of a basic unit, which was connected with a computer, a pointer and a sensory unit. The ultrasound pointer was used to define surface reference points on the back of the child (the processi spinosi of thoracic and lumbar vertebrae were palpated and marked with a pen) and comprised two markers that sent ultrasound pulses. The sensory unit received signals from the transmitters located in the measuring unit. The data were collected at a sampling rate of 10 Hz. The measuring principle was based on the timing of the interval between emission and reception of ultrasound pulses. By means of triangulation, the markers' absolute three-dimensional coordinates were calculated. Afterwards, the data were processed in thoracic kyphosis and lumbar lordosis angles with use of a soft-ware algorithm (BioAnalyse v2). Based on Coorevits et al. [9] their method for analysis of the Zebris data, the thoracic kyphosis angle was calculated as the complementary of the enclosed angle between two lines; the first line incorporated the markers representing T1 and T7 while the second line contained the markers for T7 and T12. The lumbar lordosis angle was calculated as the complementary of the enclosed angle between two lines; the first line incorporated the markers representing L1 and L3 while the second line contained the markers for L3 and L5.

The static curvatures were measured three times for two positions; while standing in anatomical position and while seating on an adjustable piano stool with a prescribed seating height for knee angles of 90°. The test leader informed the children about the three measurements for both positions. Furthermore, the children were requested to keep each position as still as possible fixating a point at eye level. When the lowest stance of the piano stool was too high for knee angles of 90°, wooden blocks were positioned to attain the prescribed 90° knee angle. For the seating condition, children were asked to take a 'correct' sitting position.

Data analysis

Data analysis was performed using SPSS 12.0. The level of significance was set at 5%. P-values between 0.05 and 0.09 were defined as a trend towards significance.

Intra-class correlations coefficients (ICCs), model 'Two-Way Mixed' type 'Consistency', were used to determine test–retest reliability with a 1-week interval for trunk muscle endurance performance and spinal curvature assessment.

To determine possible group differences between the intervention condition and the controls, the samples were evaluated in relation to anthropometrics, age and physical activity pattern performing independent-samples T-tests. In order to evaluate intervention effects on back function parameters in a pre-post design, Repeated Measures ANOVA were used. Time was included as within-subjects factor (pre vs. post) and condition as between-subjects factor (intervention versus control group). Since the change in children's weight and height over the two intervention years may affect back function, the analyses for back function parameters were adjusted when Repeated Measures ANCOVA indicated the latter anthropometrical parameters as significant covariates. Gender was analyzed as second between-subjects factor (boys vs. girls).

Results

Test–retest reliability

Mean endurance times and Single Measure ICCs for the measurement of trunk extensor and trunk flexor endurance are presented in Table 1. Very good to good reliability was found for trunk flexor (ICC = 0.82, $P < 0.001$) and trunk extensor (ICC = 0.63, $P < 0.001$) endurance testing respectively. Reliability and mean curves according to the assessment of the spinal curvature are presented in Table 2. Assessing the spinal curvature in seating position showed good to acceptable reliability for the thoracic (ICC = 0.69, $P < 0.001$) and the lumbar curvature (ICC = 0.52, $P < 0.001$), respectively. Low ICCs were found for the assessment of the thoracic (ICC = 0.39, $P < 0.05$) and the lumbar curvature (ICC = 0.37, $P < 0.05$) in stance.

Intervention effects

Both conditions were comparable for anthropometrical values, age and physical activity pattern as presented in Table 3. There were only significant differences for

Table 1 Means and test–retest reproducibility for trunk muscle endurance

Measurement (n = 47)	Endurance time (s) Mean ± SD	ICC test–retest
Trunk flexor endurance		
Test	71 ± 55	0.82**
Retest	73 ± 51	
Trunk extensor endurance		
Test	153 ± 51	0.63**
Retest	162 ± 56	

SD standard deviation of the mean, *ICC* Intraclass Correlation Coefficient

**$P < 0.001$; *$P < 0.05$

Table 2 Means and test–retest reproducibility for spinal curvature assessment

Measurement (n = 40)	Including angle (deg) Mean ± SD	ICC test–retest
Standing posture thoracic curvature		
Test	24 ± 5.9	0.39*
Retest	24 ± 8.2	
Lumbar curvature		
Test	–14 ± 7.2	0.36*
Retest	–14 ± 6.1	
Seating posture thoracic curvature		
Test	20 ± 6.4	0.69**
Retest	20 ± 6.6	
Lumbar curvature		
Test	11 ± 4.6	0.52**
Retest	13 ± 4.9	

SD standard deviation of the mean, *ICC* Intraclass Correlation Coefficient

**$P < 0.001$; *$P < 0.05$

weight at baseline and change in weight over the two school-years. The change over time for the back function parameters with regard to trunk muscle endurance, leg muscle capacity and spinal curvature is presented in Table 4.

For 'trunk flexor endurance' a significant interaction effect was found, revealing an increase in endurance time between pre-test and post-test in the intervention group compared to a decrease in the controls ($P < 0.05$). Additionally, Repeated Measures ANCOVA indicated a trend towards significance for a higher increase in 'trunk extensor endurance' time between pre-test and post-test in the intervention group compared to the controls ($P < 0.09$). No interaction effect was found for the 'ratio of trunk flexor/extensor endurance time'.

Analyzing leg muscle capacity, no interaction effect was found for the parameter 'maximal torque/body weight'. In addition, Repeated Measures ANCOVA revealed no significant interaction effect for 'total work' and 'average power' of the leg muscles.

When evaluating children's spinal curvature, no interaction effects were found for the 'thoracic' or the 'lumbar curvature in the seating position'. The children's spinal curvature in stance was not analyzed because of the low reliability using the Zebris® technique in the current study.

Finally, none of the three-way interactions (gender × time × condition) were significant when analyzing the different parameters for back function. This means that the intervention effects on back function were similar in boys and girls.

Discussion

The present study examined test–retest reliability for trunk muscle endurance testing and assessment of the spinal curvature in fourth and fifth grade elementary schoolchildren with respect to the evaluation of primary intervention effects on back function in this young study population.

Table 3 Group differences for age, anthropometrics and physical activity between the intervention and the control group of the present study sample evaluating back function parameters (Independent samples T-test)

Age, anthropometrics and physical activity	Mean ± SD		Group difference	
	Intervention	Control	*df*	*T*
Age at baseline (year)	9.8 ± 0.9	9.9 ± 0.6	66	0.829
Height at baseline (cm)	142.2 ± 8.9	140.5 ± 7.0	65.1	0.857
Weight at baseline (kg)	36.0 ± 7.4	32.7 ± 4.3	64.3	2.369*
Change in height pre-post (cm)	10.1 ± 2.3	9.0 ± 2.7	66	1.775
Change in weight pre-post (kg)	8.2 ± 3.5	6.5 ± 2.3	65.9	2.401*
Total amount of physical activity (min/week)	1,277 ± 759	1,254 ± 796	61	0.906

Intervention group: n = 41; control group: n = 28

SD standard deviation

*$P < 0.05$, $P < 0.09$

Table 4 Mean scores for back function parameters in the intervention and the control groups at baseline and at post-test

Back function parameter	Mean ± SD				Statistics
	Pre		Post		T × C
	Intervention	Control	Intervention	Control	$F_{(df=1)}$
Trunk muscle endurance					
Trunk flexor endurance time (s)	41.7 ± 27.1	48.7 ± 27.8	49.2 ± 28.7	44.2 ± 24.6	4.066*
Trunk extensor endurance time (s)	125.3 ± 55.2	159.5 ± 62.3	166.2 ± 58.3	182.1 ± 61.6	3.087$
Ratio (flexor/extensor)	0.42 ± 0.36	0.32 ± 0.19	0.30 ± 0.18	0.25 ± 0.19	0.437
Leg muscle capacity					
Maximal torque/body weight (%)	121.1 ± 21.2	130.3 ± 16.3	132.2 ± 2.9	141.7 ± 20.2	0.001
Total work (Joule)	290.3 ± 65.1	289.1 ± 53.6	441.9 ± 99.1	403.2 ± 90.3	2.399
Average power (Watt)	37.3 ± 10.9	37.5 ± 8.1	53.5 ± 15.5	49.4 ± 12.3	1.086
Spinal curvature in seating posture					
Thoracic curvature (deg)	17.8 ± 6.7	18.2 ± 7.1	17.9 ± 6.9	21.9 ± 6.3	2.714
Lumbar curvature (deg)	15.3 ± 4.6	11.6 ± 3.4	12.9 ± 3.9	11.4 ± 4.6	1.038

Control group: $n = 28$, T × C = time × condition (interaction effect), Intervention group: $n = 41$

SD standard deviation

$*P < 0.05$, $^{\$}P < 0.09$

Test–retest reliability

The present reliability values demonstrated that in 8–11-year old children the reproducibility with a 1-week interval was good for trunk flexor endurance (ICC = 0.82) and acceptable for trunk extensor endurance (ICC = 0.63). Although the reliability values of the present study were slightly lower compared to the coefficients in other reliability studies in adolescent and adult populations [2, 21, 25, 35, 38], they were still acceptable because of the young age of the participants. Motivation, fatigue, point in time of the test, feeling of pain and relationship with the test leader, are all parameters affecting reproducibility [35], especially in this young population. In the current study, the testers observed that the children were enthusiastic to perform the test to the best of their ability. Furthermore, in order to minimize variations between the performances on the test and retest measurement, measurement order, test mode, testing sequence, test leader and surrounding factors were identical during the two measurement sessions. Taking the latter into account, it can be concluded from the present study findings that the current procedure for trunk flexor and extensor endurance testing is reliable in 8–11-year-old children.

Using the Zebris® technique for the assessment of children's spinal curvature, the level of agreement between test and retest at 1-week interval showed good to poor reliability. Assessing the spinal curvature in seating position showed good to acceptable reliability for the thoracic (ICC = 0.69) and the lumbar curvature (ICC = 0.52) respectively. However, the reliability for the assessment of the thoracic (ICC = 0.39) and the lumbar curvature (ICC = 0.37) in stance was poor and lower when compared to the sitting condition. Though, a consistent measurement was aspired using standardized protocols for both the sitting condition and the standing posture. The different outcome for reliability of the standing and the sitting condition could possibly be explained by the reality that a sitting posture is more stable than a standing posture [19]. Based on these findings, we concluded that the reliability of the stance position was too low for possible interpretation of intervention effects.

Intervention effects

The study's main aim was to evaluate intervention effects of a multi-factorial back education program on children's back function. The sample of the present study included two comparable conditions. There were no differences related to height, chronological age or weekly physical activity pattern between the two conditions while the intervention children were some heavier when compared to the controls. Statistical analyses were adjusted to exclude possible interference of anthropometrical differences. The present findings showed that the two-school-year promotion of good body mechanics throughout the school curriculum resulted in increased endurance of the trunk flexors compared to a decrease of trunk flexor endurance in the control group. This finding significantly supports the effectiveness of back posture education in schoolchildren with regard to trunk flexor endurance. However, due to the higher endurance time at baseline of the trunk flexors in the control group compared to the intervention group and the relatively small changes in endurance time between the two conditions over the two school-years, the biological meaning of this effect is unknown. Furthermore, there was a trend for a higher increase of trunk extensor endurance in children who had received promotion of good body mechanics. O' Sullivan et al. [36] hypothesized that active sitting may result in a positive accommodation of the stabilizing muscles. Correspondingly, the present study's findings supported the focus on postural dynamism in the class by encouraging variable and dynamic sitting and interrupting prolonged static sitting as part of the multi-factorial back education program. Moreover, multiple prospective studies comprising adolescents [23, 41] as well as adults [44] reported trunk muscle endurance as a risk indicator for future back pain. So, one may suggest that the promotion of good body mechanics throughout the elementary school curriculum could play a key role in prevention because of the potential to improve children's trunk muscle endurance.

Furthermore, children's leg muscle capacity was evaluated as a measure of back function. During lifting tasks, the legs act as a multi-joint system (hip, knee and angle) implying activity of both the knee flexors and the knee extensors [13]. Therefore, in the present study children's leg muscle capacity was included, considering bilateral strength and endurance parameters of both knee flexors and extensors. The present multi-factorial back education program had improved children's spontaneous postural behavior during material handling conform a squat technique with a neutral spine position, as reported in a previous study [16]. However, the two-school-year back posture program in elementary schoolchildren did not result in improved leg muscle capacity in comparison to the control group.

Finally, the spinal curvature in a seating position was evaluated. In a previous study [7] it was demonstrated that children in a traditional school spend on average 97% of the lesson time in a static sitting posture, from which one-third with the trunk forward bent. Sitting and certainly sitting with a bent trunk results in a reduction of lumbar lordosis or even in a lumbar kyphosis, resulting in increased muscle effort and disc pressure [18]. Focusing on the intervention effects of children's postural behavior in the class, the children who had received promotion of good body mechanics were sitting less frequently with a flexed trunk, a flexed neck and a rotated neck during lesson time [16]. However, in contrast to the effects on sitting behavior, the spinal curvature in seating position was not changed after the promotion for good body mechanics when comparing the intervention children to the controls. The present data suggest that back posture promotion throughout the school curriculum did not change children's sitting position in a test situation and that children take a sitting position with a slightly kyphotic lumbar curvature.

A limitation of the current intervention study was the relatively small size of the study sample recommending careful interpretations of the study results. On the other hand, the present study sample was not a self-selected group since the comparison of the present sample to the total study population [16] showed no difference for anthropometrics or age and weekly physical activity.

Conclusion

The findings of the present study showed that the current procedure for trunk muscle endurance testing is reliable in 8–11-year olds. Additionally, the Zebris® technique can be used in elementary schoolchildren for the objective assessment of the spinal curvature in the seating condition. Besides, the implementation of a back education program in elementary schoolchildren resulted in improved trunk muscle endurance, but there was no change in leg muscle capacity or spinal curvature. Based on the literature, there are indications that efficient back function is important to prevent chronic back pain later in life. Therefore, back education with focus on postural dynamism in the class as an integral part of the elementary school curriculum is advocated in the scope of optimizing spinal loading through the school environment. Further, long-term investigation on the impact of school-based interventions with regard to the promotion of good body mechanics later in life is recommended.

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